Institutional Linkages and Commercialisation in Australian Biotechnology Industry: A Case Study of NSW Cluster

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Abstract: This paper describes the preliminary results of an ongoing innovation study in Australian biotechnology industry. It investigates clustering and the innovation process in selected biotechnology firms focusing on major actors and linkages among them. The research was carried out through a survey of biotechnology firms within the Sydney metropolitan area. Our findings suggest that forces external to the organisation, such as government regulation, the IP environment, and a lack of sufficient funds, are among the major barriers to the innovation process and commercialisation of innovative products. However, not all barriers are entirely external or uncontrollable. Firms in our sample have also reported resource-based barriers to innovation such as lack of skilled managers or researchers, lack of physical facilities for research or manufacturing, as well as lack of marketing resources or distribution channels.

Keywords: biotechnology clusters, innovation, linkages, commercialisation, New South Wales (NSW)

Introduction

The innovation literature has changed considerably in the past years from an individual approach to a systematic view of how large organizations achieve innovation success. It was also widely accepted that large organizations have been the main drivers for growth and innovation. More recently, innovation studies has shifted to investigating smaller firms and networks of firms. The purpose of this study is to examine the institutional linkages in Australian biotechnology industry. We examine relationships among biotechnology firms with other research institutions, universities and other partners. Furthermore, barriers to innovation and commercialisation in biotechnology and factors influencing performance in Australian biotechnology firms are analysed. The paper argues that the nature of the linkages between firms, customers, suppliers, distributors, agencies, and across sectoral boundaries – influence the scope and purpose of various business activities and the innovation process. The nature and characteristics of these linkages often help to determine the effectiveness of the innovation process at local, national and international levels.

The biotechnology sector is comprised of biotechnology firms, research institutions, and related industrial companies that discover, develop, and commercialise biotechnological; products and processes. While the US has the largest and most diverse biotechnology industry, the Australian industry has also grown considerably during the past decade. For example, the availability of biotechnology investment capital in Australia has improved tremendously. However, Australia's ability to attract and retain top scientists and to remain competitive in the biotechnology industry depends on continued support from both government and private sources.

Australian biotechnology firms agglomerate in locations with strong technological infrastructure. The largest agglomerations in Australia are located in New South Wales (NSW), Victoria (VIC), and Queensland (QLD) (Fayle, 2000). Taken together, companies in these clusters are responsible for the bulk of biotechnology innovative activity in Australia. State government initiatives are being implemented to strengthen relationships between biotechnology industry leaders and university or government research institutions toward the common goals of industry cohesion and growth. The three regions of NSW, VIC and QLD have a strong research base,

and significant university-industry linkages in place, which promotes infrastructure sharing and technology transfer. These relationships have enabled the regional industry to grow and prosper in recent years (DSDI, 2004).

Central to recent innovation studies on regional clusters is the idea that overall innovation performance of an economy depends not so much on how specific organisations perform but how well they interact with each other (Lundvall, 1992; Nelson 1993). In this perspective the notion of an innovation system has been analysed at several levels ranging from sectoral and enterprise specific innovation systems, to local, national, regional and global systems of innovation (Freeman and Soete, 1997; Cooke and Morgan, 1998).

This research contributes to empirical investigation of innovative activities and linkages among a cluster of biotechnology firms in Sydney area. It builds on previous research to evaluate the nature of connections, linkages and partnerships as key factors in distinguishing clusters (Camagni, 1991; Porter, 1998; Enright, 1998; Cooke and Morgan, 1998; Mitra, 2000). It presents the results obtained from a survey carried out in Sydney in 2002. The primary objective of this research is to evaluate the interaction and degree of linkage between biotech companies with locally and nationally-based companies, and institutions such as customers, suppliers, universities and public research institutions. The methodology also permits some evaluation of activities in the innovation process of the firms and their assessment of the suitability of the local environment for innovation and commercilisation. The second objective of this study is to assess both external and internal barriers to innovation faced by these companies and their impact on innovation success. Before presenting the empirical results, a brief introduction to the NSW biotechnology cluster is provided in the next section.

NSW Biotechnology Cluster

As with other nations, biotechnology R&D is developing in geographic clusters, primarily through the proximity of universities, hospitals and medical or agricultural research institutes with essential business and financial services (Cooke, 2003). Clustering may be either evolutionary by building on existing local attributes, or more formal through planned and purpose built technology parks (e.g. housing designed incubation facilities). Porter (2002) has suggested that Australia has groups of companies within the one industry that were forming clusters which ultimately create a critical mass that can set a global standard. According to Porter, examples of these clusters are horse breeding, wine production, defence technology and biotechnology (Porter, 2002).NSW accounts for about 40% of the biotechnology companies in Australia and has demonstrated strong research capabilities in pharmaceutical discovery, medical devices and agriculture. In Sydney, primarily in recent years, important clusters in biotechnology have emerged, combining expertise and resources to achieve scientific breakthroughs. The NSW Government is proactive in promoting biotechnology

and has provided significant support for the establishment of the Australian Technology Park (ATP) in Sydney, a major centre for biotechnology research, as well as other research parks (DSRD, 2001). The ATP, based in central Sydney and supported by three major universities, is a dynamic research campus with a focus on biotechnology. Tenants benefit from the location of Johnson & Johnson research on site and purpose-built facilities. The ATP operates as an incubator fostering the growth of start-up companies in several fields such as biotechnology, photonics, multimedia and advanced internet services. These companies aim to become independent within three years, ready for investment from established venture capital funds.

The Macquarie University Research Park also provides an interface between the university and commercial enterprises. The Australian Proteome Analysis facility and Macquarie Research Ltd, which is the licensing and consulting arm of Macquarie University, are also located within the park. Another cluster located in the Riverside Corporate Park based on the CSIRO campus in Northern Sydney. In this location, industry works closely alongside government researchers in a variety of fields including molecular sciences, food sciences, agriculture and mining. Industries also benefit from being close to North Ryde, a major concentration of biotech firms.

In NSW, the largest independent medical research institute is the Garvan Institute of Medical Research. The Garvan combines laboratory facilities and clinical research capabilities as well as major research programs in cancer, arthritis, osteoporosis, diabetes, and mental health. Other major research institutes include the Centenary Institute for Cancer Medicine and Biology, the Walter and Eliza Hall Institute, Australian Genomic Research Facility, the Biomolecular Research Institute and the Centre for Drug Design & Development.

Research Context: Innovation and Clusters

Innovation is critical for biotechnology firms in sustaining their competitive advantage in the industry. Developing products or processes from scientific breakthroughs and bringing those products to the market is a long and costly process, with no guarantees of commercial success. Funding is the lifeblood of biotechnology as firms spend millions of dollars on research and development. The innovation process can be quite complex because basic research, product development, as well as manufacturing and distribution of a commercial product can include several sector players. Strategic alliances and other collaborative agreements among universities, biotechnology firms, and larger industrial companies (e.g. pharmaceutical companies) are widely used methods of achieving innovation. The ways in which partner companies combine resources to achieve innovation and the key determinants of successful innovation efforts in biotechnology have been the focus of recent research (see, for instance, McKelvey, Alm & Riccaboni, 2003; Marsh, 2003).

For example, knowledge spillovers, inter-firm relationships, utilisation of shared resources, a well-developed local skills base, and the evolution of the region through tacit and explicit knowledge exchange, are

typical features of regional clusters mentioned in the literature (OECD, 1999; Storper, 1997; Simmie and J. Sennett, 1999). These features also provide the basis for social and economic 'connectivity' that underlines the operation of firms in clusters.

The definition of clusters as "groups of firms in the same industry, or in closely related industries that are in close geographical proximity to each other" is meant to include geographically concentrated industries including so-called 'industrial districts' (Enright, 1998:337). The geographic concentration of interconnected firms is supported by interconnected suppliers, downstream channels, customers, manufacturers of complementary products, and can also extend to companies with complementary skills (Porter, 1998). Clusters also include public institutions, including government education institutions, and support services, with cluster boundaries being defined by linkages and complementarities across institutions and industries (Porter, 1998).

Merging the idea of regional innovation and clusters lies in the understanding of the successful evolution of clusters whereby their formation, organisation and structure are themselves features of an innovation process. The innovation process in biotechnology has been described as the sequence of activities by which an idea is transformed into a commercial product (Rothwell 1994). These activities, in their simplest form, consist of research, product development, manufacturing, and marketing. Although this schema implies that the innovation process in biotechnology is strictly linear, feedback and interaction among the elements of the process are inherent as is true in any industry (Kline and Rosenberg, 1986; Malecki, 1997).

It should be noted that not all biotechnology firms attempt to take ideas from the research stage to the market. Firms may pursue innovation from basic research and discovery and follow through all the way to the commercialisation and distribution of a product. Conversely, biotechnology firms may specialise in a certain phase of the innovation process. Drug discovery companies, for example, operate in the basic research and product development stages, licensing their technologies to suitable companies in biotechnology or the pharmaceutical industry. In any case, innovation lies at the heart of biotechnology firm strategy.

The evolution of innovation from the early stages of research to market commercialisation has resulted in clusters attracting public and private finance, chambers of commerce and trade associations generating commercial market research, regional government providing industry-specific infrastructure, and local educational institutions doing industry-specific training and research. This combination of integrated and leveraged activity is often at the heart of innovation and collective learning as the literature on innovation highlights (Rosenberg, 1982; Malecki, 1997).

The literature also refers to firms in clusters *learning to innovate* through a systematic application of various competencies and a more productive use of their assets (Mitra, 2000). The learning process is continuous and tends to take place even when innovations are not apparent (as in incremental innovations). In biotechnology, learning is active and competencies might include: competitive manufacturing; competency in marketing, commercialisation and distribution networks; and the ability to deal with the regulatory procedures

involved in getting new products onto the market.

It is often argued that academics, biotechnology firms and large firms bring distinctive advantages to the creation of biotechnology innovations. Initially, scientific expertise which lay in the science base, are gradually transferred to the biotech firms as they develop their own R&D competences (Cooke, 2003). Large firms initially lacked the R&D competences to innovate in biotechnology themselves, but they had all complementary assets necessary to commercialise discoveries, such as manufacturing skills, marketing and distribution networks and experience with regulatory processes. These distinctive organisational advantages provided the basis for considerable amounts of collaboration and interactions between the different groups.

The Australian biotechnology industry consists of mostly small and medium-sized firms. Early on, small start-ups benefited from government research funds and infusions of funds from other sources. While start-up firms may possess the funding for research and early stages of commercialisation, they often lack the necessary testing facilities, manufacturing capabilities nor marketing channels to be successful in launching innovation products into the market. It is often difficult for biotechnology firms to attract financing to carry them through the entire innovation process. Therefore, a firm may have to combine different sources of capital like public funds, venture capital, national research contracts and debt financing to sustain operations (Greis et al., 1995). Finally, firm size, government regulation, and funding are all barriers that may have a strong impact on the ability of biotechnology firms to becoming innovative and successful in commercialising their products. Within this context, our study attempts to identify the main barriers to innovation in selected biotechnology firms in the Sydney region. It also argues that the nature of the linkages within the cluster of these biotech companies influences the scope and purpose of their various business activities and the innovation process.

Data and Methodology

To address the above issues, research was carried out through a survey of firms within the Sydney region of NSW. The sample of firms included in the study was drawn from the Australian Biotechnology Directory. From a total sampling base of 58 core biotechnology companies in Sydney, a sub-sample of 44 firms was chosen to receive questionnaires. The four-page questionnaire was first mailed to 44 biotechnology companies in Sydney area. Follow-up telephone calls and emails were also made. In total sixteen usable responses were received, yielding a response rate of 36%.

A structured questionnaire was designed to map the perceived importance of clusters, linkages, financial flow and barriers to innovation and commercialisation within the area. The questions were formulated in two different ways: (a) 'factual' questions requiring a dichotomous (yes/no) response; and (b) questions which were answered on scale-type responses, indicating intensity of the linkages, location and importance of the information and knowledge ranging from little importance to very important. Additionally, follow up

discussions held with senior managers of selected firms in order to investigate in more qualitative detail the nature of the local cluster and commercialisation process within the firms.

Table 1: Origin of biotech firms

Origin of Firm (N=16)	
Branch plant	3
Entrepreneur SMEs	8
Uni Spin-off	2
Public R&D Spin-off	1
Corporate Spin-off	1
Incubator Co.	1

Source: Sydney Survey

Table 1 provides data on origin of the firms. Majority of the firms (8) were formed by an entrepreneur as a small business and out of 16 firms only 4 firms were spin-offs either from a university or a public research centre. As an example, in one case the University of Macquarie has served as an incubator for a new biotechnology firm, providing researchers with the resources necessary to commercialise scientific discoveries. Industrial spin-off accounted for only 1 firm out of respondents.

Institutional Linkages

This section examines the relationship between these biotechnology firms and institutional linkages with other organizations. We were particularly interested in asking the following questions: Which partners do firms interact with in the innovation process? How important are these interactions? and where are those firms located? We can see from Table 2 below that there are strong interactions between these firms, universities and their customers. This is consistent with other literature findings asserting that innovation in biotechnology firms often takes place interactively with major research universities (Kline and Rosenberg, 1986; Dosi, 1998).

Table 2: Institutional Linkages among Biotechnology Firms (N=16)

Linkages			**Frequency**			
	Never	**Seldom**	**Frequently**	**Always**	**Mean**	**Rank**
Universities	2		12	2	1.87	1
Customers	3	3	4	6	1.81	2
Suppliers	3	3	5	5	1.56	3
Foreign partners	1	7	6	2	1.56	3
Consultants	5	2	8	1	1.31	4
Public R&D Centres	4	4	7	1	1.31	4
Private Research Institutes	5	5	5	1	1.12	5
Hospitals	5	6	3	2	1.12	5
Other firms	4	2	8	2	1.12	5
Venture Capital firms	9	4	3		0.62	6

Note: 0=Never, 1=Seldom, 2=Frequently, 3=Always
Source: Sydney Survey

Customers frequently provide ideas for product development and modifications as well as for new products and they may contribute substantially to the design and development process. In the case of medical instruments, for example, suppliers were reported the trigger of innovation, through the provision of better performing components or new materials. Also they often contribute to the required process technology. Frequently these relations are not of the market type (short term) but interactive and more durable (network).

Interestingly, customers and suppliers as innovation partners are not confined to the region but for our sample of the firms more frequently located at the national and even global level. While a few firms indicated that their customers are local, the majority of them have customers located outside the local region of Sydney and often have international customers.

Links with public research providers such as public R&D centres were also reported to be strong especially with CSIRO centres in Sydney area. This 'strong relationship', however, was not the case with venture capitals firms. It was rather surprising to find that there was relatively little mention of venture capital firms as innovation partners. Partly this may be because the services of these institutions are regarded as being not tailored to the real needs of these firms. While venture capital firms are becoming more common and gaining increasing relevance with Australian biotechnology industry, use of these entities still appears to be limited, although there is evidence of increasing use among SMEs in high-tech sectors.

Consultants, however, seem to play a relatively important role in the commercilisation process of these companies. They provide know-how in various relevant fields, from legal aspects of patenting and licensing to consulting with respect to technology-access, innovation management and marketing/distribution. Due to the specialised nature of the required knowledge, they are not only drawn from the local region but from the national level as well.

Foreign partners or other firms seem to have a notable relevance as being other potential partners. Interestingly, there was a significant degree of contact between companies with foreign partners, but also between companies within the same or different industry sectors. Out of 16 firms 6 companies reported that they had either frequent or constant contact with companies from other countries, with only 1 reporting no contact. Also, 8 firms reported either frequent or constant contact with firms within the same or other industry sector, with 4 firms reporting no interaction.

On the whole, the results together with comments by interviewees, suggest that there is significant contact and collaboration between these biotechnology firms and other institutions whether being a research centre in a university setting or a public R&D centre.

Commercialisation Hurdles

Australian universities and public research institutions are increasingly active in promoting the commercialisation of intellectual property. Most NSW universities and government research institutions have a

specialised commercialisation unit or incorporated arms for managing the commercialisation of research outcomes. For example, Unisearch Limited, which is the commercial arm of Sydney's University of New South Wales (UNSW), is the most active technology commercialisation company in Australia with a portfolio of over 250 patents, 30 existing licence agreements and equity interests in four technology spin-off companies.

In line with the increase in technology transfer and commercialisation activity of these institutions, the number of start-ups has risen considerably with a record 45 firms formed in the 2000/2001 financial year (Hopper & Thorburn, 2001). The data also indicates that research institutions have been more accepting of spin-offs as a technology transfer tool. A growing proportion of biotech firms are spin-offs from research institutions. According to a recent report (Hopper & Thorburn, 2001), the proportion of spin-offs hit almost 70% of all new start-ups and the overall trend is 58% over the last five years.

According to another Biotechnology Report (Ernst & Young, 2001) most of the companies that have been surveyed are developing technology from their founders or in-licensed from universities and the CSIRO. On the basis of this report, almost half of Australia's biotechnology companies have been created to commercialise inventions and discoveries of one or more of their founders rather than by in-licensing new technologies. However, the report indicates a healthy diversity of sources of new business ideas as many companies are also active in licensing from universities and the CSIRO.

Given the fact that most of the Australian biotechnology industry consists of mostly small and medium-sized firm, we were interested in identifying barriers to success of these smaller firms. We asked our respondents to indicate potential barriers and their significance to innovation and commercialisation (Table 3). The most significant barrier reported in our sample of firms was lack of funds. These results seem reasonable considering that product sales consist of the main sources of R&D funding for new established firms operating in earlier-stage of innovation. Therefore, the judicious use of limited resources is crucial to the success of their innovation process. The issue of funding for new established firms is also high on the agenda of the State's and Federal's biotechnology initiative (Biotechnology Australia, 2000).

Personal interviews with managers indicated that the Australian regulatory process is also one of the greatest barriers to innovation and commercialisation. Lack of qualified personnel and a lack of manufacturing facilities report significantly high by the Sydney firms. Another barrier to innovation reported by firms is lack of skilled managers. These findings support earlier reports about Australian biotechnology industry asserting that the major obstacles to product development and commercialisation included difficulty raising funding or insufficient funding, heavy government regulation or a long approval process, and a lack of qualified managers.

Table 3

Barriers to commercialisation (N=16)	Number of Firms
Excessive perceived economic risks	6
Costs too high	10
Lack of appropriate sources of finance	9
Organisational rigidities	2
Lack of qualified personnel	8
Lack of information on markets	5
Fulfilling regulations, standards	8

Source: Sydney Survey
Note: Multiple choices allowed

Other findings in our study suggest that collaboration with universities or research centres were important factors in explaining firm's performance. Reports by respondents indicate that forces external to the organisation were among the main barriers to their innovation. These included, government regulation, intellectual property regime, and a lack of government research funds. Collaboration with universities, research centres and industrial companies was rated more important than collaboration with other biotechnology firms. In an industry where collaboration is prevalent, it may be expected that as the Australian industry matures, collaboration may play an even more important role in firm performance.

However, not all barriers are entirely external or uncontrollable. Many firms reported resource-based barriers to innovation such as lack of skilled managers or researchers, lack of physical facilities for research or manufacturing, as well as lack of marketing or distribution channels. In fact, the most significant factors to which firms attributed their innovation performance were internal rather than external. Product quality, speed of product development, the ability to reorganise the commercial applicability of technology and firms' managerial skills were among the highest-rated factors.

Personal interviews with several managers from sample firms support the above findings. For example, one of the questions asked was if (innovation in their firms was driven by scientific breakthrough or by market demand or need). Managers for the most part maintained that innovation is initially science-driven, and for some firms this was a disadvantage because they had no products ready for market launch. Firms with products on the market maintained that while scientific advances were the cornerstone of innovations, the projects that received funding and approval to move ahead with marketing activities were more successful in getting their products ready for market launch, for example diagnostic tests for a specific disease, or a therapy for known disease.

Discussion and Conclusion

In the context of a more systematic innovation approach this study investigated how innovative activities of biotechnology firms are organised and the importance of linkages with other industry agents. We have

presented our initial results from a survey of biotechnology firms in the Sydney area of New South Wales (NSW). In meeting the first objective of this study we explored the benefits of innovation and commercialisation through clustering and a process of innovation management to build on the advantages of new technology and innovation.

Our results indicate that biotechnology firms which regularly carry out R&D through collaboration and networking achieve higher average rates of turnover and make a greater contribution towards providing employment. The findings, however, also suggest that not only horizontal partnerships with research institutions and universities cooperation plays a distinctly important role in innovation linkages of the sample firms, but also vertical relationships with suppliers and customers seem important for these firms.

As for the importance of locality, it appears that the regional range of innovative linkages is focused primarily on national levels. While linkages with customers and suppliers are very intensive with partners across Australia and overseas, collaboration with universities and training institutions often takes place in the closer vicinity. This is probably due to the tacit character of knowledge transfer between these partners, where face-to-face contacts are a prerequisite for joint innovation projects. These findings suggest that while these firms operate within a local cluster, substantial links exist to suppliers and customers outside the region. This is particularly true for more innovative firms, which extend their operation nationally and globally.

Overall, the necessity to link and network with outside organisations seems to be essential for our sample group. For the larger companies, which have resources, experience, capital backing and established reputation, these connections are relatively straightforward and common-place practice. In fact, they have become integral to the way business is conducted. However, the smaller companies still lack the benefits of institutional linkages and need to further develop their connections with universities, venture capital firms, public research organisations, funding agencies and training establishments. Local competencies in research institutions or knowledge services can be an important source of innovation activities for these smaller firms. These institutions could play a far more important role than they do at present. However, as our research suggest, biotechnology firms tend to make use more of locally trained skilled staff in their business and focus on innovative activities rather than rely on other forms of collaboration.

In sum, by studying the examples of clustering, both regional policy makers and firm managers can make decisions, which are aimed at improving the innovation process and competitiveness capabilities. In forming effective policies both at the level of the firm and the region, decision makers may need to consider the learning process inherent in the management of externalities and internalities, especially in dealing with uncertainty and complexity.

Ensuring effective technological connectivity coupled with appropriate management know-how is perhaps essential for these high-tech firms. It may, enable them to better connect, particularly in their knowledge base, learning processes and competencies, with their business environment. Also, from a policy

development point of view it is critical to understand the evolutionary stages of innovation in the firm as well as the cluster in which the firm is located. Of equal value, is the recognition of the each stage in the evolutionary process that offers its own opportunities for managing innovation both at the level of the firm and the cluster.

Finally, it is important to consider the main critical factors of innovation success in the context of institutional linkages and cluster theory. In fact, although clusters are highly individual and differentiated, it is helpful to identify some common factors of success and, in particular, their innovative capability, linked to continuous learning at level of single firm and at the level of the systems of firms which refer to collective learning and learning by interacting.

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